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INFRARED THERMOGRAPHY OF BUILDINGS: QUALITATIVE ANALYSIS OF WIN--ETC(U)
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INFRARED THERMOGRAPHY OF BUILDINGS

Qualitative Analysis of Window Infiltration Loss

Federal Office Building, Burlington, Vt.

Richard H. Munis
Stephen J. Marshall

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An interior, infrared thermographic survey of single-pane, aluminum-frame, projected windows was performed to pinpoint locations of excessive infiltration. Infrared thermographic inspection accomplishes this more quickly and more accurately than conventional techniques of studying window infiltration. This report presents 32 thermograms and photographs which in many cases dramatically illustrate infiltrations (1) around the mullions, (2) along the top opening cracks, and (3) under the frame/sill interfaces. Poor glazing seals

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were easily detected and the exact points of glass/frame leakages were pin-pointed. Plumes of warm air on the window glass, rising from the convectors, were dramatically captured by the infrared camera system. In several cases, the plumes were noted 12 ft. above the convectors on the top window panels. Heat loss from the convectors was noted through the walls of the building in thermograms taken from the outside. Several recommendations were prepared for the General Services Administration, owner of this Federal Office Building in Burlington, Vermont.

PREFACE

This report was prepared by Dr. Richard H. Munis, Research Physicist, and Stephen J. Marshall, Physical Science Technician, Physical Sciences Branch, Research Division, U.S. Army Cold Regions Research and Engineering Laboratory.

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INTRODUCTION

On the evening of 31 March 1977, a heat loss survey of the Federal Office Building in Burlington, Vermont, was conducted to determine the extent of conduction and infiltration losses from windows throughout the building. The Federal Office Building is a six-story brick structure with single-pane glass in all the windows. All the windows in the building are projected except the non-opening windows in the lobby of the Post Office. An AGA Thermovision infrared camera system was used to conduct this survey (see Fig. 32).

Most of the survey was performed from inside the building because of the pressure differential generated by the wind which was gusting in excess of 24 mph out of the northwest during the survey. Temperatures inside the building varied between $72^{\circ}F$ and $75^{\circ}F$.

ANALYSIS

In any building which has single-pane windows, the conduction loss through the glass is the most obvious source of heat loss. An infrared camera system can be used very effectively to demonstrate this type of heat loss even though it may not be necessary to do so. However, a not-so-obvious source of heat loss is the air leakage (infiltration) through the framing spaces of windows and through the clearance spaces around the sashes (opening parts) of windows. It is usually not easy to determine whether or not extensive infiltration losses exist at the windows of a building unless a thermographic inspection of the windows is made. Once the windows are inspected using this method, the locations of all air leakage around each window can be pinpointed accurately.

Most of the projected windows in the Federal Office Building in Burlington have aluminum frames, which are a source of heat loss by conduction. However, the thermograms taken inside the building indicate that infiltration of cold air around the opening sash and around the framing space of each window constitutes a major source of heat loss.

Figures 1 and 2 show thermograms of two north-facing windows in Room 621 taken from inside the building. The infiltration (arrows) seen around these windows is typical of the condition observed at all of the randomly selected windows during the thermographic inspection of this building. Note that in Figure 2 the infiltration is more extensive than in Figure 1. The horizontal black line between the two arrows in Figure 2 shows cold

air leaking through the seal at the top of the opening window. Generally speaking, the air leakage at this location was not as severe as it was around the framing space of these windows. Figure 3 is a photograph of three windows in Room 621.

Figure 4 is a thermogram of the top left part of another projected window in Room 621. Note that air leakage at the window opening is minimal compared with leakage through the window framing space. Also, note in the three thermograms shown in Figures 1, 2 and 4, and in all subsequent ones, that the aluminum frames do not constitute a source of heat loss quite as severe as the infiltration losses.

Figure 5 is a thermogram of cold air leakage under the frame of the opening sash of a window in Room 621. This leakage is probably due to a deficiency of caulking, whereas in the previous three thermograms (Figs. 1, 2 and 4) lack of insulation in the framing space results in excess heat loss.

Figure 6 is a thermogram showing the comparative difference between the heat loss through the framing space (horizontal arrows) and the heat loss under the frame of the opening window (vertical arrows). In this situation, there is more heat loss through the framing space than under the window frame.

All of the previous thermograms were taken of windows adjacent to opaque wall sections. Figure 7 is a thermogram of a window which is bounded on each side by another window. The top arrow points to cold air

leaking around the seal at the top of the opening window. The lower right two arrows identify cold air leaking around the mullion between this window and an adjacent one. The arrow at the lower middle identifies a location of greater leakage under the frame of this window than at the other two locations mentioned above.

Figure 8 is a thermogram of a window showing heat loss due to infiltration around the mullion (top arrow) and around the glass-aluminum frame interface (bottom arrows). The heat loss at the latter location could be due to a poor glazing seal. However, it is difficult to determine from the thermogram which pane of glass is not glazed properly. The black arrow identifies excess air leakage around the top seal of the opening window.

Figures 9 and 10 are thermograms of two north-facing opening windows in Room 629. The arrows identify excess air leakage entering the room through the interface of the glass and aluminum frame. As in the case of Figure 8, the heat loss around these windows could be due to an inadequate glazing seal. Figure 11 is a thermogram of the lower left corner of another window in Room 629 having a situation similar to those in Figures 9 and 10.

Figure 12 is a thermogram of an opening window on the northeast corner of Room 631. The top arrow identifies heat loss at the top opening crack, the middle arrow locates air leakage around the mullion, and the lower arrow shows air leakage under the aluminum frame.

Figure 13 is a thermogram of the top left section of an east-facing opening window in Room 631. The cold air leakage is fairly uniform around the mullion and the top opening crack. Figure 14 is a thermogram of the

same window but taken below the frame at the sill level. Notice that while the infiltration remains constant up the left side of this window the air leakage under the frame is more severe due to a poorly caulked joint.

Figure 15 is a thermogram of a section of a north-facing opening window in Room 234. This particular window abuts an opaque wall section. The thermal pattern seems to indicate that the infiltration is taking place through the framing space of the window. Obviously, it is much worse at the lower part of the window than at the upper part. However, at the top opening crack no air leakage is visible.

Figures 16 and 17 are thermograms of mullions of north-facing stationary windows in Room 234. The excess heat is probably being lost at the glass/aluminum frame interface in a manner similar to the situation in Figures 8-10.

Figure 18 is a thermogram of the top opening crack of a north-facing window in Room 234. The uniform, thin, black horizontal line indicates air leakage at the top opening crack, while the arrow points to excess heat loss at the glass/frame interface. The glass pane in the opening window shows leakage at two locations (arrows). Figure 19 is a thermogram of the lower right corner of the same window. While there is some cold air present at the sill/frame interface, the greatest heat loss (arrow) seems to be at the bottom right corner of the glass/frame interface.

Figure 20 is a thermogram of two south-facing basement windows in the Post Office workroom. Figure 21 is a photograph of these windows.

Personnel stated that they were very cold when working near these windows. In fact, this section of the workroom was not used during the winter months for this reason. The thermogram shows the convection of cold air from each of these single-pane windows.

Figure 22 is a thermogram of two other south-facing windows in the Post Office workroom. The arrows identify the usual sources of heat loss found in all the other windows inspected during this survey. However, the general appearance of the thermal pattern of the window on the right indicates why it is so cold working near these windows.

Figures 23 and 24 are thermograms of the lower sections of the east-facing stationary single-pane windows in the Post Office lobby. Arrows identify a plume of heat rising from the convectors directly under these windows. Figure 25 is a thermogram of the top section of one of these windows. The arrows locate the warm spots on the glass due to the heat rising from the convectors. Figure 26 is a photograph of these windows.

The remaining thermograms were taken from the outside of the building. In these thermograms, excess heat losses are identified by bright thermal patterns rather than the dark patterns observed in all of the preceding thermograms.

Figure 27 is a thermogram taken directly outside the Post Office lobby; thus it can be compared with Figures 23-25. This thermogram proves beyond a doubt that the plume of heat is being readily conducted through the single-pane glass. Also note that the convectors themselves are transmitting heat (arrows) directly through the masonry wall. Figure 28

is another thermogram showing heat being conducted through the masonry wall. This is the south-facing wall of the Post Office workroom where radiators and hot water pipes are mounted directly to the wall.

The remaining three thermograms (Figures 29-31) show the heat loss from east-facing windows. The windows having "bright" thermal patterns either have warmer interior temperatures than the ones that do not, or in some cases, the "dark" windows have a higher thermal efficiency due to the presence of drapes.

Without a thermographic inspection of this building, it could have been assumed that the only significant source of heat loss is the single-pane glass in all of the windows. However, our inspection of randomly selected windows indicates that a substantial amount of heat is leaking around the glass and around the frame of each window. We did not find a single window that could be considered thermally efficient although some windows were more efficient than others.

RECOMMENDATIONS

This thermographic analysis indicated that all the windows inspected showed serious signs of air leakage at various locations. This evidence therefore lends credibility to any recommendation that suggests a retrofit program, which would involve a major renovation. Before proceeding further, various retrofit options with their advantages and disadvantages will be discussed.

When air leakage around windows is a major problem, as it is in this building, there are several possibilities for correcting the situation. One corrective action would be to improve the glazing seals in all of the windows, recaulk the windows and add fiberglass or foam insulation around the framing space of each window. Obviously this approach would involve a labor intensive solution that, while significantly reducing the overall heat loss through infiltration, would have no effect on the heat loss by conduction through the single-pane glass. Another approach would be to remove all existing windows and install double- or triple-glazed windows throughout. When the new windows are installed, the framing spaces could be heavily insulated to reduce excessive air leakage. This second alternative would be both labor and capital intensive but would result in an even greater reduction in the overall heat loss around and through each window.

If new windows the same size as existing ones are installed, it is assumed that the <u>total glass area will remain the same as before</u>. However, if a decision is made to <u>reduce the total glass area</u> the reduction can be done in two ways. The first method is to install windows with

less glass area and more insulated panel area. The disadvantage of this method, however, is that if the frames were solid aluminum without any thermal break, conduction losses would nullify some of the savings realized by decreasing the glass area. The second method of reducing glass area is to use exterior wall insulation and finish to block up large expanses of glass. This approach has an advantage in that, not only will heat losses be reduced to an even greater extent (about 60%) than in the first method, but expensive glass and sash maintenance will be eliminated. Furthermore, when the glass area is blocked up, it may be possible to eliminate some of the wall-mounted convectors which may no longer be needed.

Whatever the final decision regarding the amount of glass to be retained, we recommend that heavy lined drapes also be used on all of the windows. Use of these drapes at night and during all non-working hours could reduce the overall heat loss by another 5%.

Perhaps just as important as the amount of glass to be retained is the type of glass that should be used if new glass is to be installed. It is a common misconception that insulating glass with 1/4-in. air space is a satisfactory substitute for single-pane glass. Preliminary infrared thermographic tests carried out four years ago at CRREL showed that a storm sash with an air space about 1-1/4 in. is superior to the conventional insulating glass. In other words, it is the size of the air space that controls the magnitude of the heat losses.

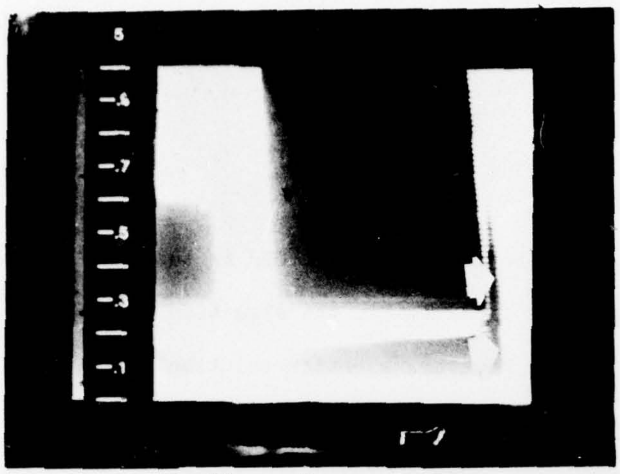
Recently, it has come to our attention that one of the major window manufacturer's is now producing an insulating glass with 13/16-in. air space. In our view, this should be the minimum size of any air space in order for it to be effective in reducing heat loss. Therefore we recommend that, if any windows are to be replaced in this building, either those with storm sashes separated by at least 1 in. from the exterior windows be installed or insulating glass with an air space of about 1 in. be considered.

The discussion relating to the windows considered the retrofit options for all of the projected windows which opened. However, referring to Figures 23, 24, 25 and 27, we see that significant heat losses are occurring through the stationary windows in the Post Office lobby. To effect a significant reduction in heat loss, two possible corrective actions can be taken: 1) reduce glass area according to our previous recommendations or 2) retain the same glass area but install double- or triple-glazed windows. In either case, we also recommend that 1) aluminum reflectors be placed behind the convectors to deflect the heat back into the lobby, 2) heavy lined drapes be used during all non-occupancy hours, and 3) the temperature in the lobby (and in the whole building) be maintained at 68°F during occupancy hours, and reduced to 65°F at night.

Figures 27 and 28 show evidence of excessive wall heat losses through the lower part of the east-facing wall (Post Office lobby) and the lower part of the south-facing wall (Post Office workroom). While the area involved is not extensive, these losses could be up to 5% of the total BTU loss of this building.

If aluminum reflectors can be inserted behind the convectors in the Post Office lobby so that they extend to the floor level, the situation shown in Figure 27 can be greatly remedied. However, a better solution can be achieved to reduce the wall heat losses shown in Figure 28. The wall can be insulated using various methods. If an approved finishing material is used for covering and fire codes permit, urethane could be sprayed on the wall. Urethane has the highest thermal resistance (R) factor of any commercially available insulation. Other possibilities include the use of rigid urethane or Styrofoam, fiberglass insulation, and urea formaldehyde insulation. GSA management personnel will have to assess the trade-off between relocating pipes on or near this wall, and the cost of installing insulation with the savings that could be realized.

This report has provided a wide range of possible corrective actions that can be taken to effect a significant reduction in energy (heating) consumption of this building. The most important decision that must be made by GSA management personnel is how much glass wall area can be converted into opaque wall area. If the glass area can be reduced significantly, then the potential savings will be greatly increased.



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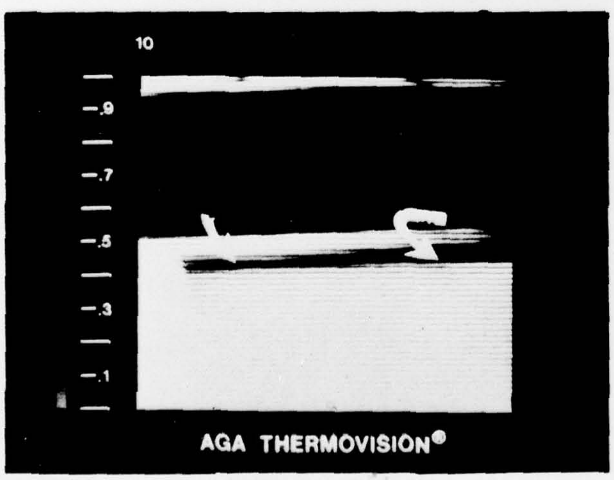

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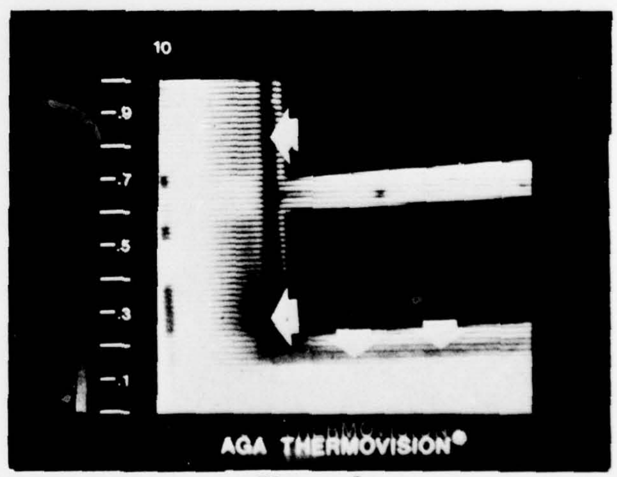

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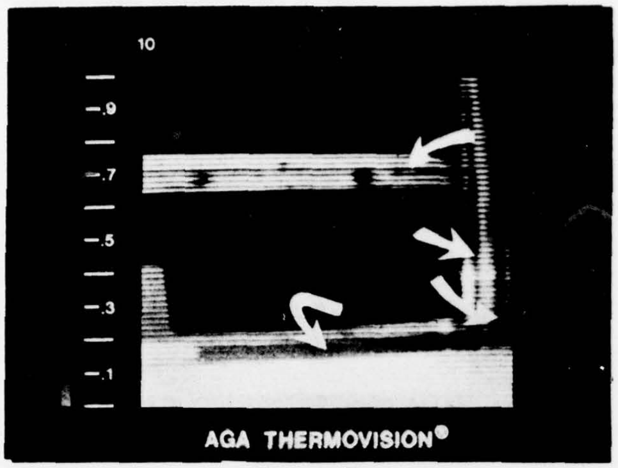

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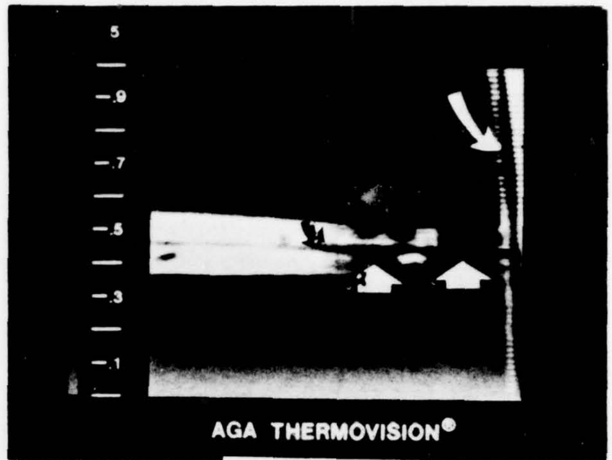

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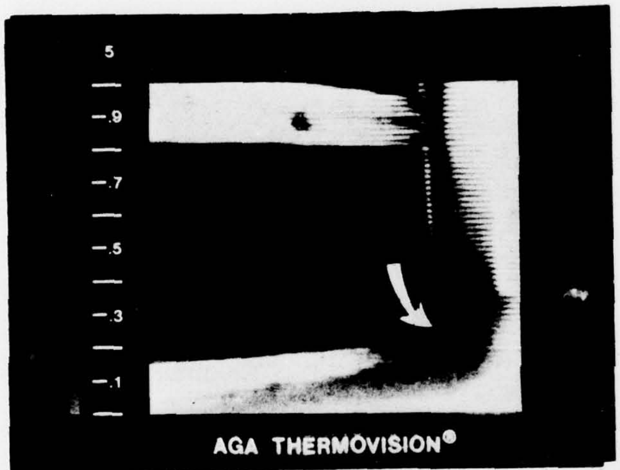

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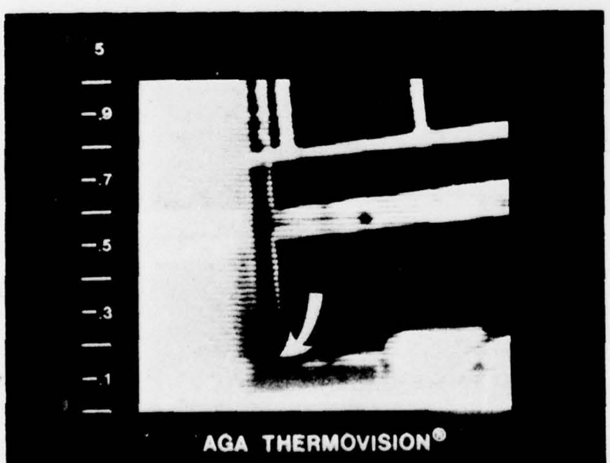

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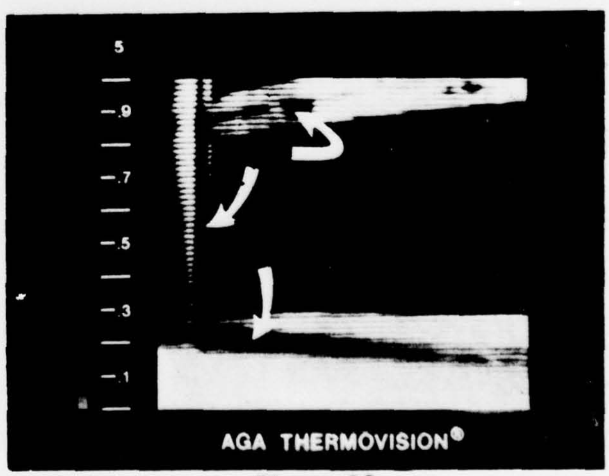

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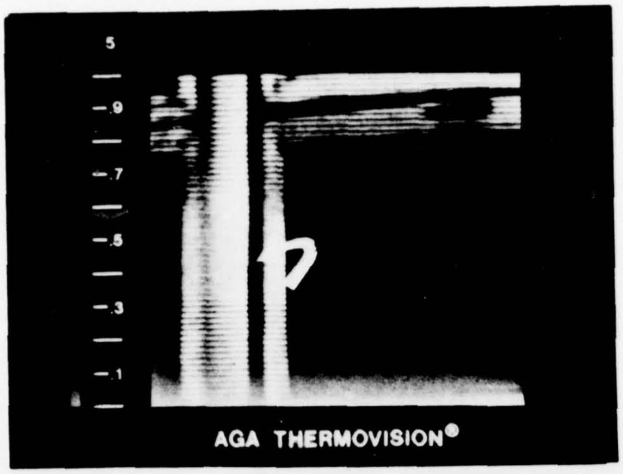

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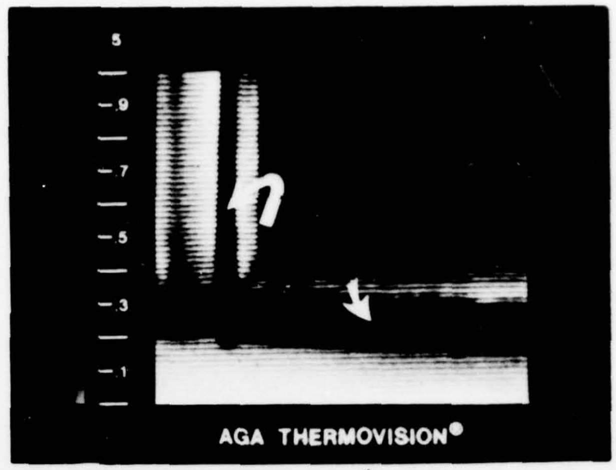

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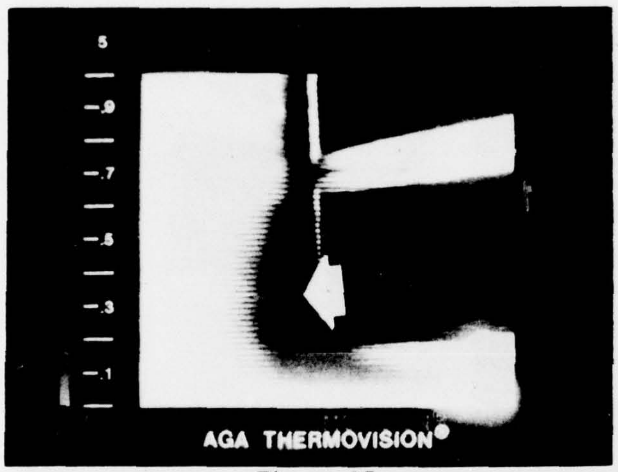

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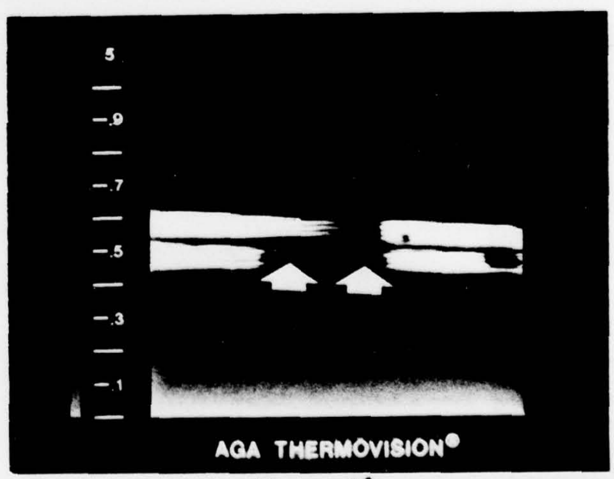

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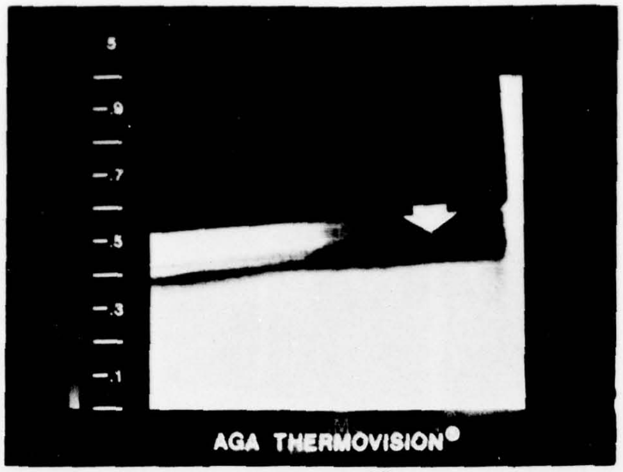

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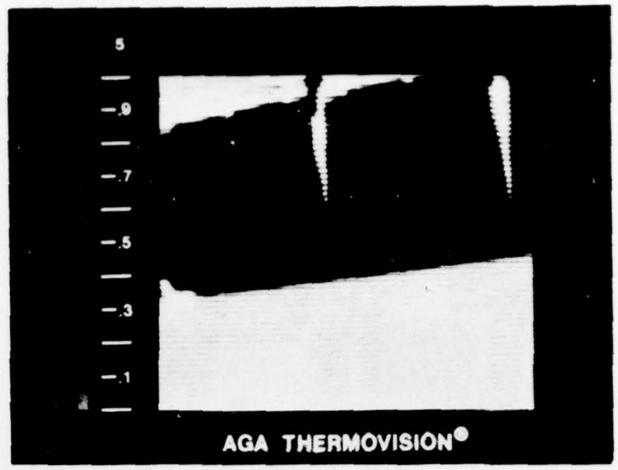

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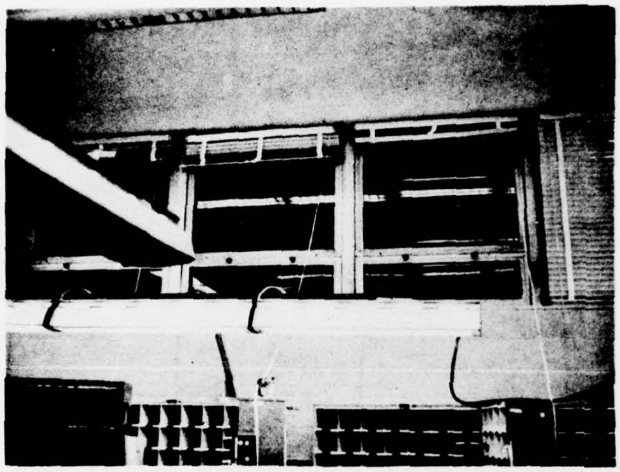
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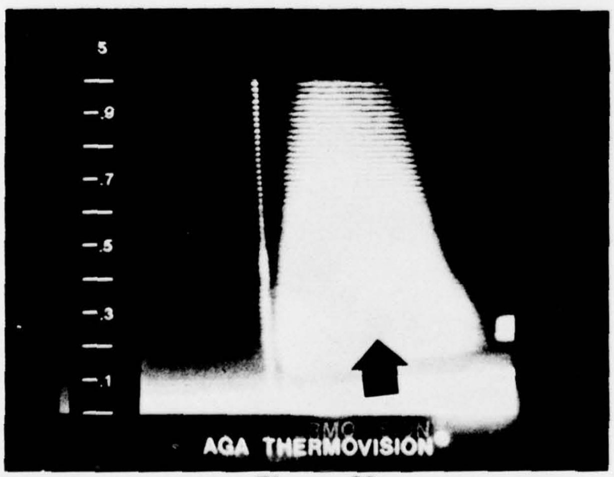

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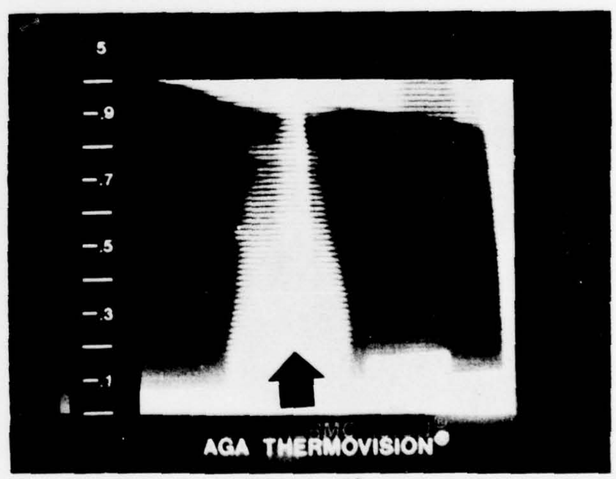

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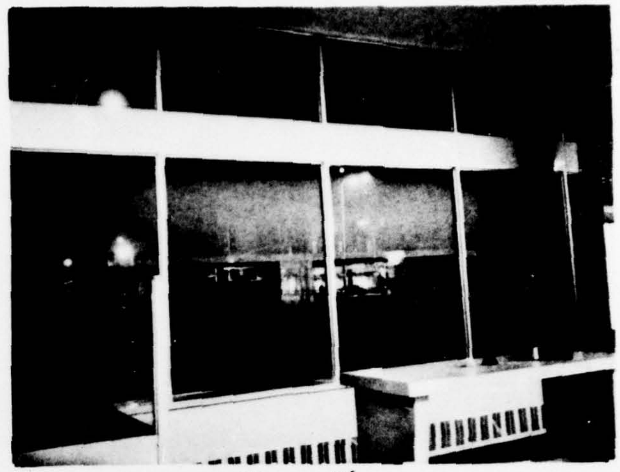
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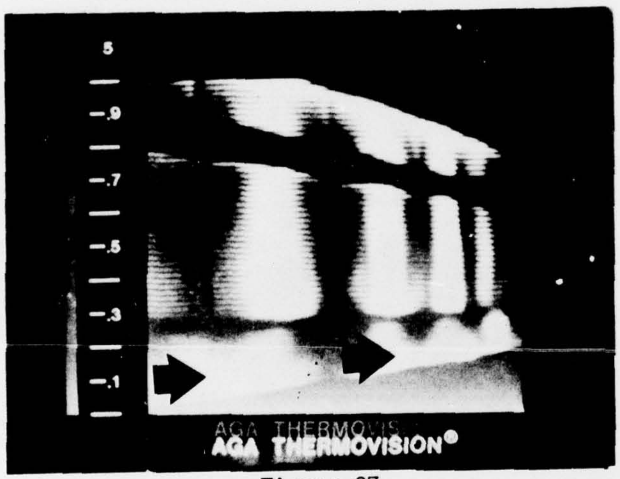

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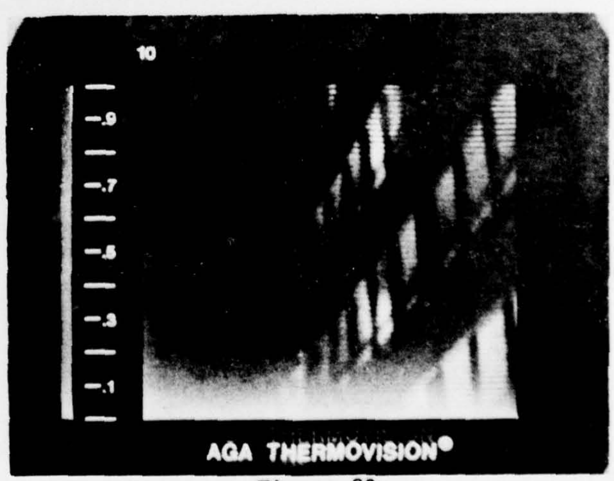

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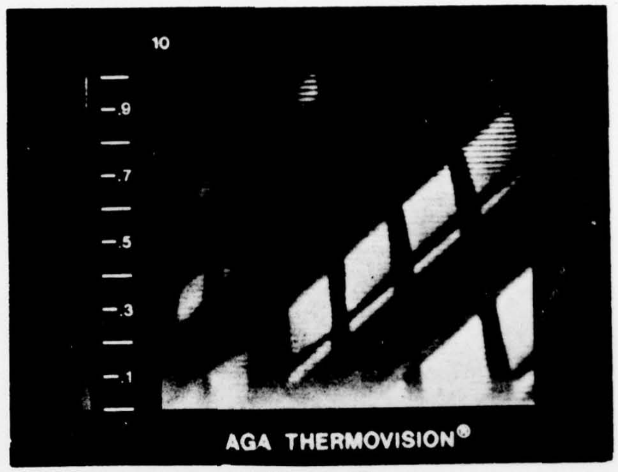

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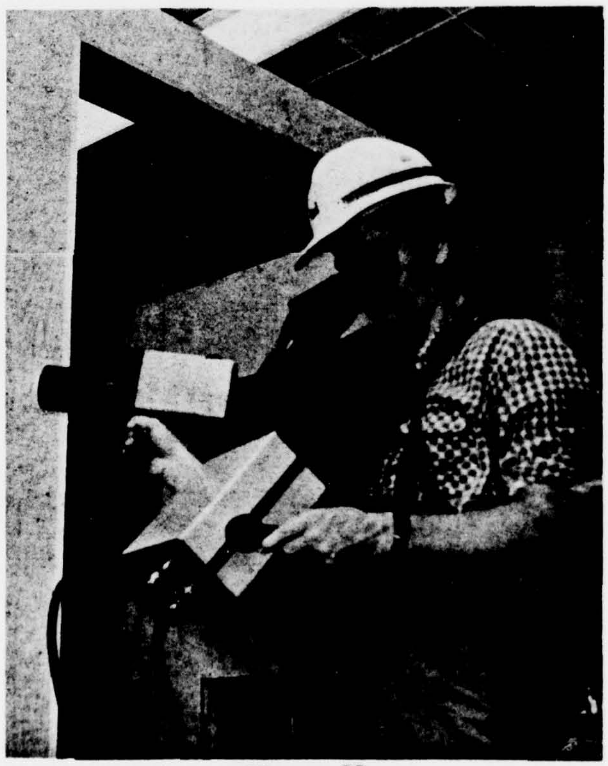

Figure 32.